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SUBMISSION OF SUBSTITUTE SPECIFICATION

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Attached is a Substitute Specification and a marked-up copy of the original specification. I certify that said substitute specification contains no new matter and includes the changes indicated in the marked-up copy of the original specification.

Respectfully submitted,

June 18, 2001

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STRUCTURED PRE-FORM BODIES FOR SOUND ABSORPTION

BACKGROUND AND SUMMARY OF INVENTION

[0001] The present invention relates to structure pre-form bodies consisting of open-cell foamed material presenting a comparatively solid framework co-vibrating in a resonant manner at low frequencies as panel lining for wide-band sound absorption.

[0002] Structured sound-absorbing panel linings are known for the application in acoustic free-field spaces, which consist of a porous material and present substantially a wedge-shaped or pyramidal geometry [1, 2, 3, 4]. This outside geometry is realized with both compact shaped or pre-formed bodies [1, 2, 3] and also with layers or other element assemblies [4].

[0003] The acoustic classification [1] of these panel linings is mainly determined by a frequency-independent high degree of absorption at an orthogonal incidence of sound. The lower critical or limit frequency, from which onwards this high absorption level is reached, is of particular importance because it is decisive for the total thickness of the panel lining. Conventionally structured linings are governed by the relationship that the lining thickness corresponds roughly to one quarter of the wavelength of the lower limit frequency when a 99% degree of absorption is required. This furnishes a lining thickness of roughly 0.85 meters at a lower limit frequency of 100 Hz. In view of this magnitude it becomes evident that a reduction of the lining by roughly 40% saves not only some volume of the structure but also enlarges the measuring radius in the space [5] with an unvaried high degree of absorption.

[0004] The present invention is based on the problem of designing the pre-form bodies according to prior art in a way that the structural depth may be made smaller while the acoustic characteristics are retained at a constant level.

[0005] This problem is solved by the pre-form bodies according to the present invention.

[0006] The pre-form bodies consist of a plane base layer of a defined thickness on the side of the wall as well as a columnar structure positioned directly in front of the base layer and having a defined distribution of height and cross-section in the manner of a wide-band tuned moderator gap. The maximum columnar height corresponds expediently to the thickness of the base and the columns have a one-side bevel cut on a room side whilst the moderator gap has a one-side bevel cut on its base side.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Fig. 1: structure of the inventive pre-form bodies consisting of the base layer (1) and the column array (2) with an bevel cut (3) on the room side;

[0008] Fig. 2: exemplary combination of the inventive pre-form bodies to form a large-side panel lining;

[0009] Fig. 3: structure of the inventive pre-form bodies with the angle w of the one-side bevel cut (3);

[0010] Fig. 4: combination of the inventive pre-form bodies with a composite panel resonator (4);

[0011] Fig. 5: structure of the inventive pre-form bodies with the flattening (5) on the room side of the array of columns (2) presenting a one-side bevel cut;

[0012] Fig. 6: structure of the inventive pre-form bodies with the protective cover (6) on the room side;

[0013] Fig. 7: exemplary inventive pre-form bodies (total thickness 520 mm);

[0014] Fig. 8: exemplary conventional panel lining consisting of mineral-wool panels (total thickness 650 mm);

[0015] Fig. 9: contrastive comparison of the measured degrees of absorption for an orthogonal sound incidence of the inventive pre-form bodies according to Fig. 7 against a conventional panel lining according to Fig. 8; and

[0016] Fig. 10: illustration of the waste-free cutting of the inventive pre-form bodies.

DETAILED DESCRIPTION OF THE DRAWINGS

[0017] The pre-form bodies according to the present invention consist of an open-cell foamed material presenting a comparatively solid framework co-vibrating in a resonant manner at low frequencies, such as the cellular melamine resin known by the trademark BASOTECT®. The sound absorption by this material is defined, on the one hand, by its porosity, i.e., by the conversion of sound energy into thermal energy due to friction. On the other hand, the comparatively rigid framework surrounding the open cells creates the effect of an acoustic mass whose movement or deformation, respectively, represents a further resonance-like mechanism of absorption. This resonance distinctly increases the absorption at low frequencies, with the resonance frequency being shifted farther towards low frequencies as the thickness of the layer increases.

[0018] The starting point of the inventive pre-form bodies is therefore a plane base layer (1) having the thickness H1 (between 200 and 500 mm, preferably 250 mm) and made of such a cellular material as is illustrated in Fig. 1, which, in distinction from layers of foamed material producing negligible framework vibrations at low frequencies and having a degree of absorption of almost 1. A BASOTECT® panel, 150 mm thick, may be mentioned as an example, which absorbs already 99% of the orthogonally incident sounds energy at roughly 125 Hz (Fig. 9).

[0019] In the range of medium and high frequencies, the sound absorption is due to the sound impedance in combination with the thickness of the cellular material. Depending on the thickness of the layer, however, a range of up to 15% reduction in sound absorption occurs between these two high-absorption frequency ranges. To balance this reduction a tuned array of columns (2) of cellular material in front of the base layer (1) is joined in the inventive pre-form bodies. At a defined length H2 (in the order of H1) and with square cross-sectional areas (D1, D2, B1, B2 according to Fig. 1 between 50 and 200 mm so that D1+D2 and B1+B2 produce preferably 250 mm), these columns define square hollow chambers in the manner of moderator gaps (Fig. 2) which terminate, on one side, at the base layer (1) and open into the space on the other side.

[0020] The dimensioning of this moderator gap is oriented by the frequency range within which the base layer (1) alone presents an insufficient sound absorption characteristic. Essential design parameters for the moderator gap are its length and the thickness of the lateral attenuation layer. In the exemplary BASOTECT® panel, 250 mm thick, a column height of roughly 250 mm and a column cross-section of approximately 125 mm x 125 mm has been found to be

a suitable column geometry. The further optimization of the inventive pre-form bodies encompasses, *expressis verbis*, different or varying cross-sections of the columns and hence a non-symmetrical design of the moderator gap. The columns of cellular material present a one-side bevel cut (3) at the room-side end so as to avoid an abrupt impedance transition on the surface of the lining. The cutting angle (w) according to Fig. 3 amounts to roughly 35°, relative to the plane of the wall. For the same reason, the moderator gaps terminate on the base side equally in the afore-described cut, rather than in a plane form.

[0021] An embodiment of the inventive pre-form bodies consists in their combination with a composite panel resonator (4)[6] which is employed also in plane sound-absorbing panel linings [7] for extending the frequency range of high sound absorption towards the low frequencies. In the case of a combination with the inventive pre-form bodies, the base layer (1) is connected to the vibrating metal sheet of the composite panel resonator (Fig. 4) on its rear side, e.g., by means of adhesive bonding. Further practical embodiments of the inventive pre-form bodies are acoustically transmissive covers (6) made of non-woven or woven material or perforated panel material for mechanical protection of the lining (Fig. 5). The acoustically almost inefficient flattening (5) by up to 30 mm on the bevel cuts (3) on the room side, which is illustrated in Fig. 6, is provided to this end in order to ensure a partially plane support of large-side cages made of perforated panels.

[0022] The advantages of the inventive pre-form bodies over existing structured panel linings for sound absorption relate to the following features:

- For a specified lower limit frequency, from which onwards a degree of sounds absorption as high as possible must be achieved, a distinctly smaller structural depth (roughly 40%) is sufficient for the inventive pre-form bodies.

- As a result of the rigid framework of cellular material, of the concurrent low weight of unit volume (10 kg/m^2) and the small structural depth (of roughly 500 mm), the inventive pre-form bodies are inherently stable or self-supporting and do not require any holding structure. An adhesive bond on the rear side for attachment to the wall of the room is sufficient for fastening, for instance.

- The acoustically almost inefficient flattening (5) of the bevel cuts on the room side assists the use of covers (6), e.g., with perforated panels, so that a plane lining surface is created that is protected on the side of the room.

- Anti-trickle protection, as it is required, for instance, for panel linings consisting of a fibrous material, is not required.

- There are numerous possibilities of optimizing the production of the inventive pre-form bodies because the fibre-free material is, on the one hand, suitable for prefabrication with optional dimensions and, on the other hand, easy to mount.

- The inventive pre-form bodies are cut from the typical blanks (blocks of cellular material with a size of 1.25 m x 1 m x 2.5 m or panels with an area of 1.25 m x 1 m) in a way that cuttings or waste will not be products, as is illustrated in Fig. 10.

[0023] An exemplary comparison of the inventive pre-form bodies (Fig. 7) against conventional structured wall absorbers (Fig. 8) renders the savings in structural depth with a simultaneously increased measured sound absorption (Fig. 9) even more evident, particularly at low frequencies.

Literature

[1] DIN Standard 45635, Part 1, Annex B 1.2

[2] N.N.: "Reflexionsarme Schallmessräume für Forschung" *[Low-reflection sound-measuring spaces for application sin industry and research]* (company pamphlet), G + H Montage GmbH, 1992

[3] U.S. Patent No. 5,780,785, Acoustic absorption device and an assembly of such device

[4] Rother, P.; Nutsch, Jr. "Prinzip und Andwendung einer neuartigen Wandverkleidung für reflexionsarme Räume" *[Principle and application of a novel panel lining for low-reflection spaces]*, 4th Intern. Congress on Acoustics (ICA), Copenhagen 1962, page M44.

[5] Babuke, G.; Fuchs, H.V.; Teige, K.; Pfeiffer, G.: "Kompakte reflexionsarme Auskleidung für kleine Messräume" *[Compact low-reflection lining for small measuring spaces]*, in: Bauphysik 20 (1998), No. 5, pages 157-165.

[6] German Patent No. DE 19506511, Composite panel resonator

[7] German Patent DE 19738757, Low-reflection room lining for the entire audible range.